

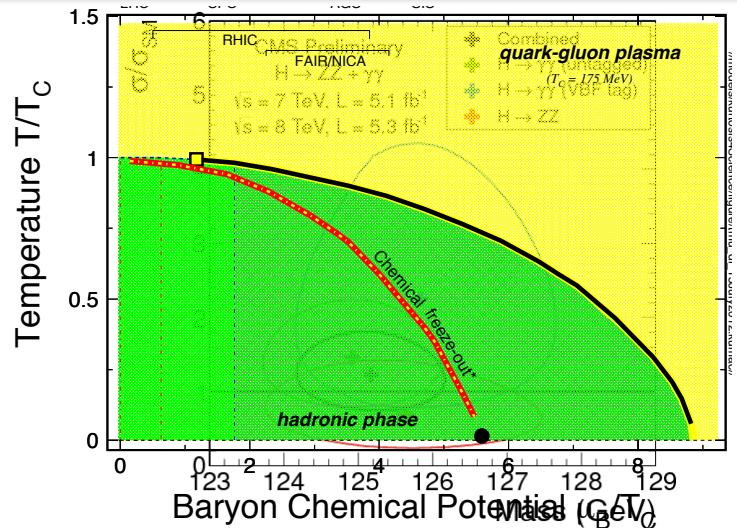
EMERGENT PROPERTIES OF THE QCD MATTER

# Heavy Flavor Hadron Correlations in High-Energy Nuclear Collisions

Nu Xu<sup>(1,2)</sup>

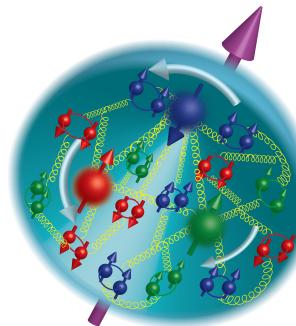
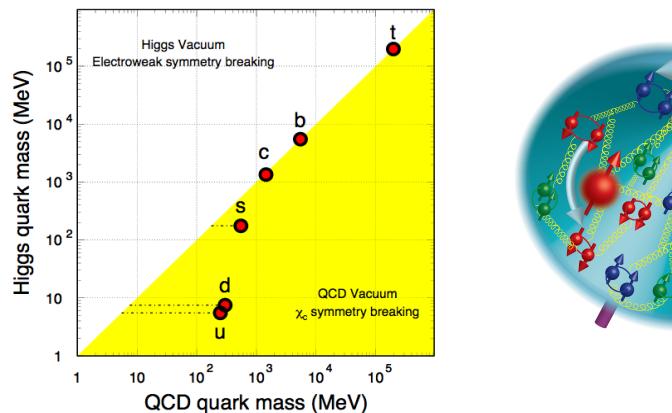
<sup>(1)</sup> College of Physical Science & Technology, Central China Normal University, Wuhan, 430079, China

<sup>(2)</sup> Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

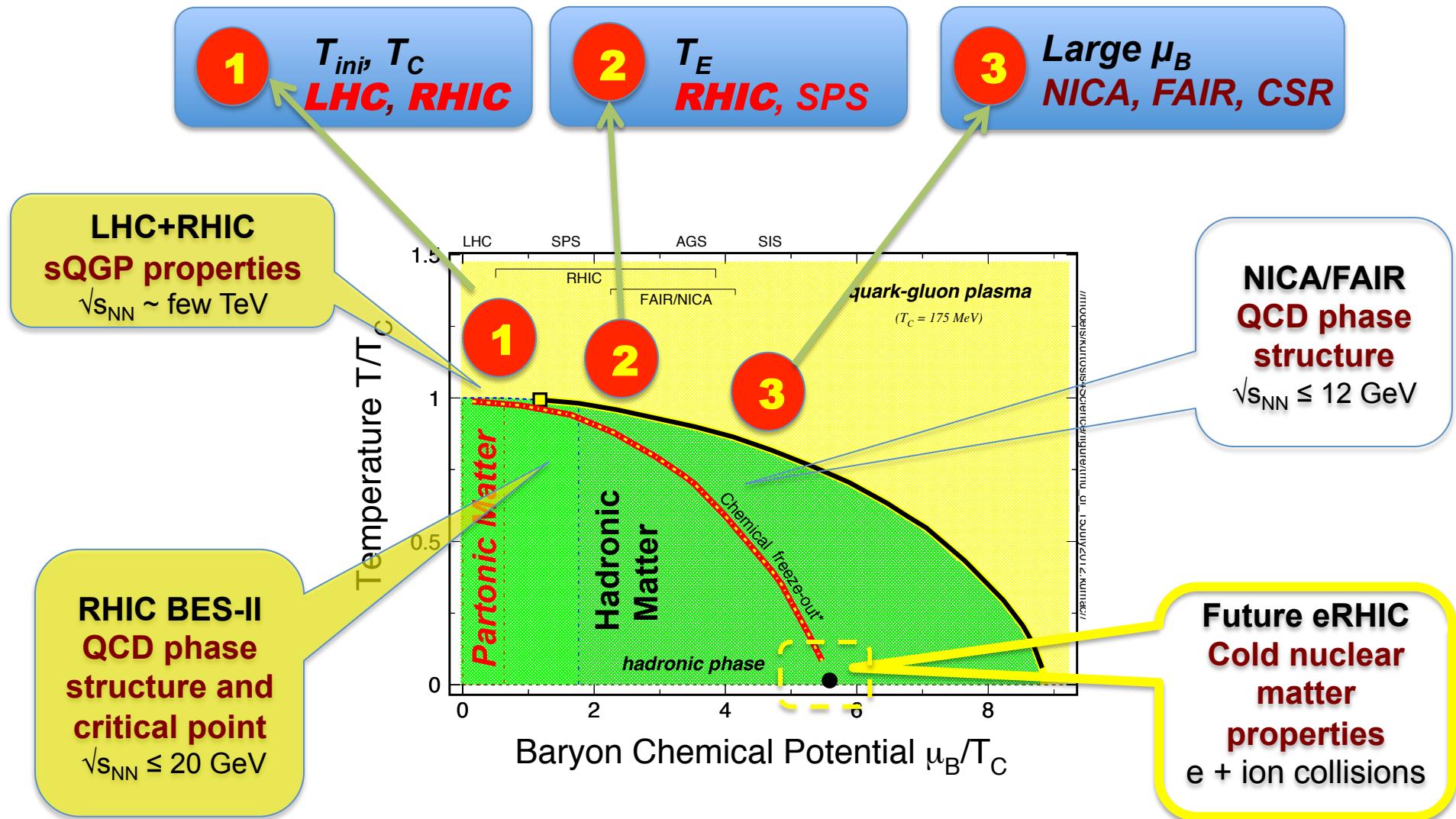


**Emergent properties with QCD degrees of freedom!**

- (1) Higgs (-like) Particle –
  - Origin of Mass, QCD dof
  - Standard Model → The Theory
  
- (2) QCD Emerging Properties –
  - Confinement,  $X_c$  symmetry
  - QCD Phase Structure
  - Nucleon helicity structure
  - ...
  - Non-linear QCD at small-x
  - ...



# Exploring the QCD Phase Structure



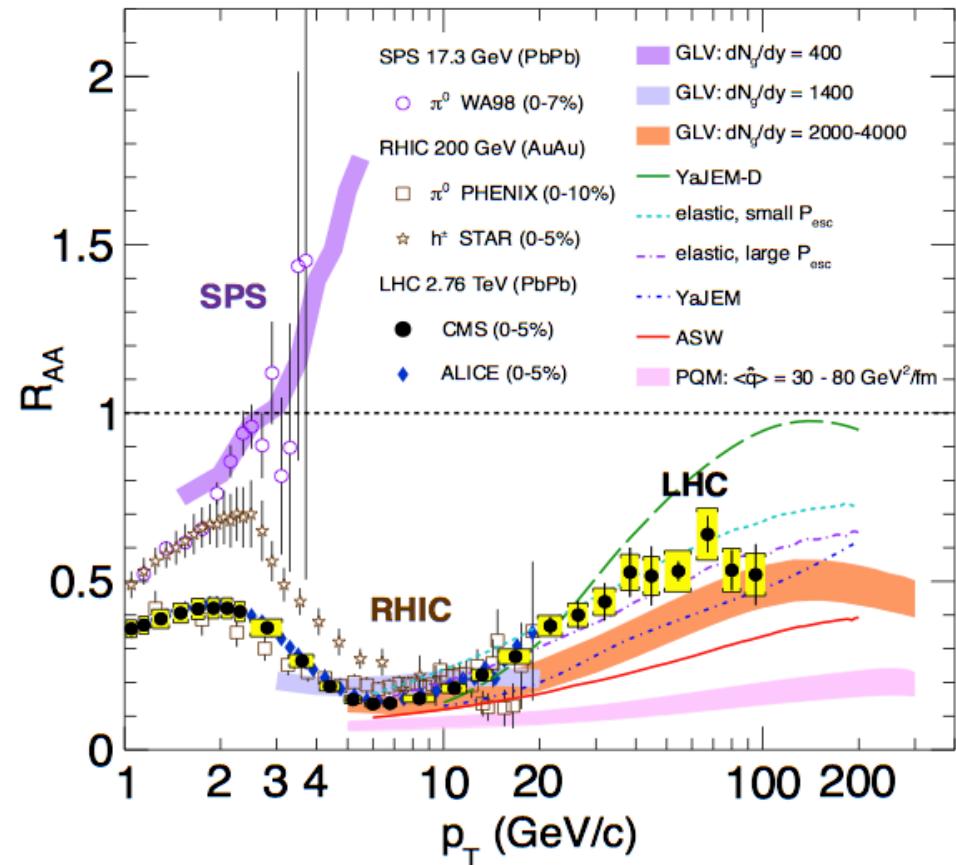
# Jets at SPS, RHIC and LHC

Nuclear modification factor:

$$R_{AA} = \frac{dN^{AA}/dp_T}{\langle T_{AA} \rangle d\sigma^{pp}/dp_T}$$

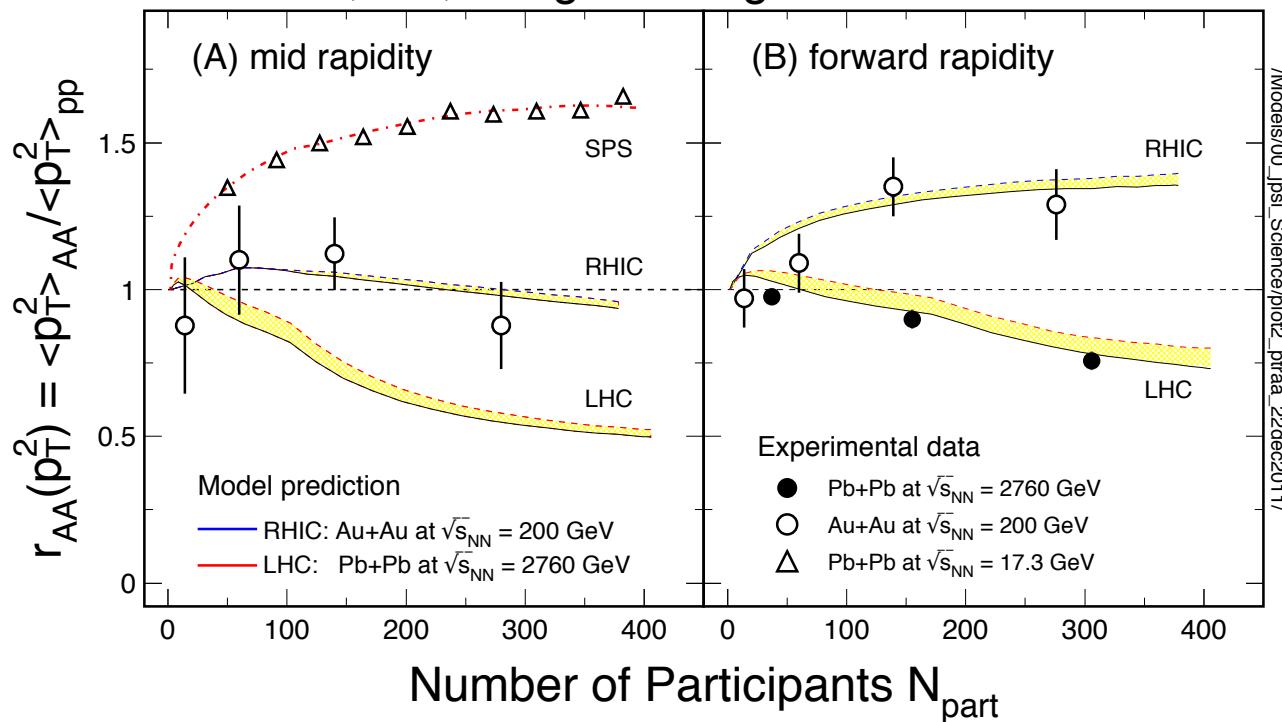
$$\langle T_{AA} \rangle = \frac{\langle n_{coll} \rangle}{\sigma_{inel}^{NN}}$$

$$R_{CP} = \frac{dN^{AA}/dp_T / n_{coll}|_{cent}}{dN^{AA}/dp_T / n_{coll}|_{per}}$$



- 1) Stronger suppression at higher collision energies
- 2)  $R_{AA} \sim 0.5$  for charged hadrons at high  $p_T$  ( $\sim 100$  GeV/c) in central Pb+Pb collisions

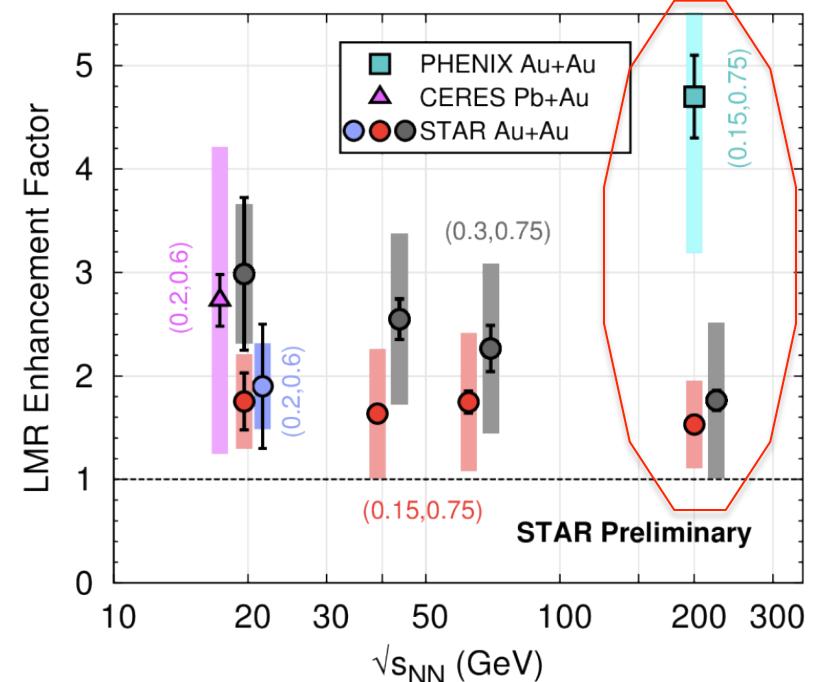
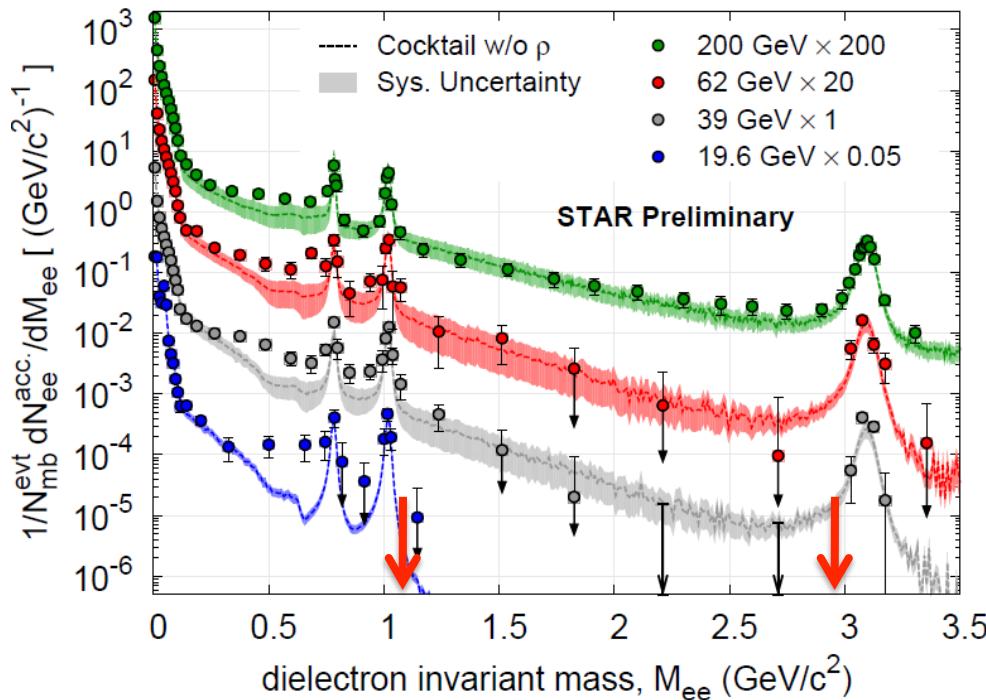
Kai Zhou, NX, Pengfe Zhang



$$r_{AA}(p_T^2) = \langle p_T^2 \rangle^{AA} / \langle p_T^2 \rangle^{pp}$$

Identify the production mechanism and the properties of the medium: *shadowing, initial scattering effect, collectivity, regeneration*, etc, one should study  $p_T$ - $r_{AA}$

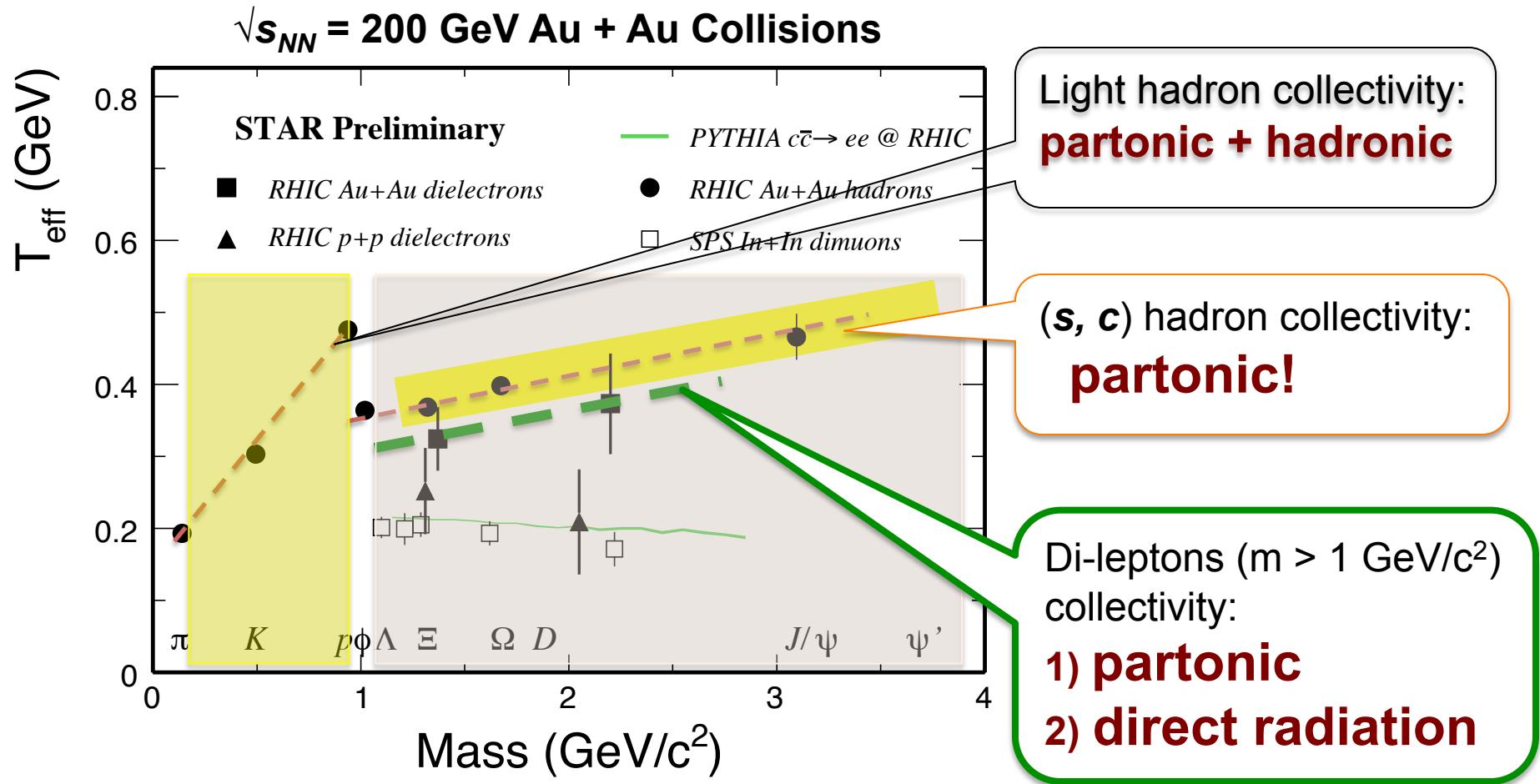
# Di-electrons: $\sqrt{s_{NN}}$ Dependence



- 1) Di-lepton: ***penetrating-bulk probe***
- 2) LMR: no significant energy dependence in enhancement
- 3) Future: focus in  $1 < m_{\parallel} < 3 \text{ GeV}/c^2$ , to
  - Measure correlated charm contributions
  - Extract direct radiation information

# Future: Partonic Collectivity, Direct Radiation

STAR: Y. Zhang, CPOD2011; J. Zhao, QM2011

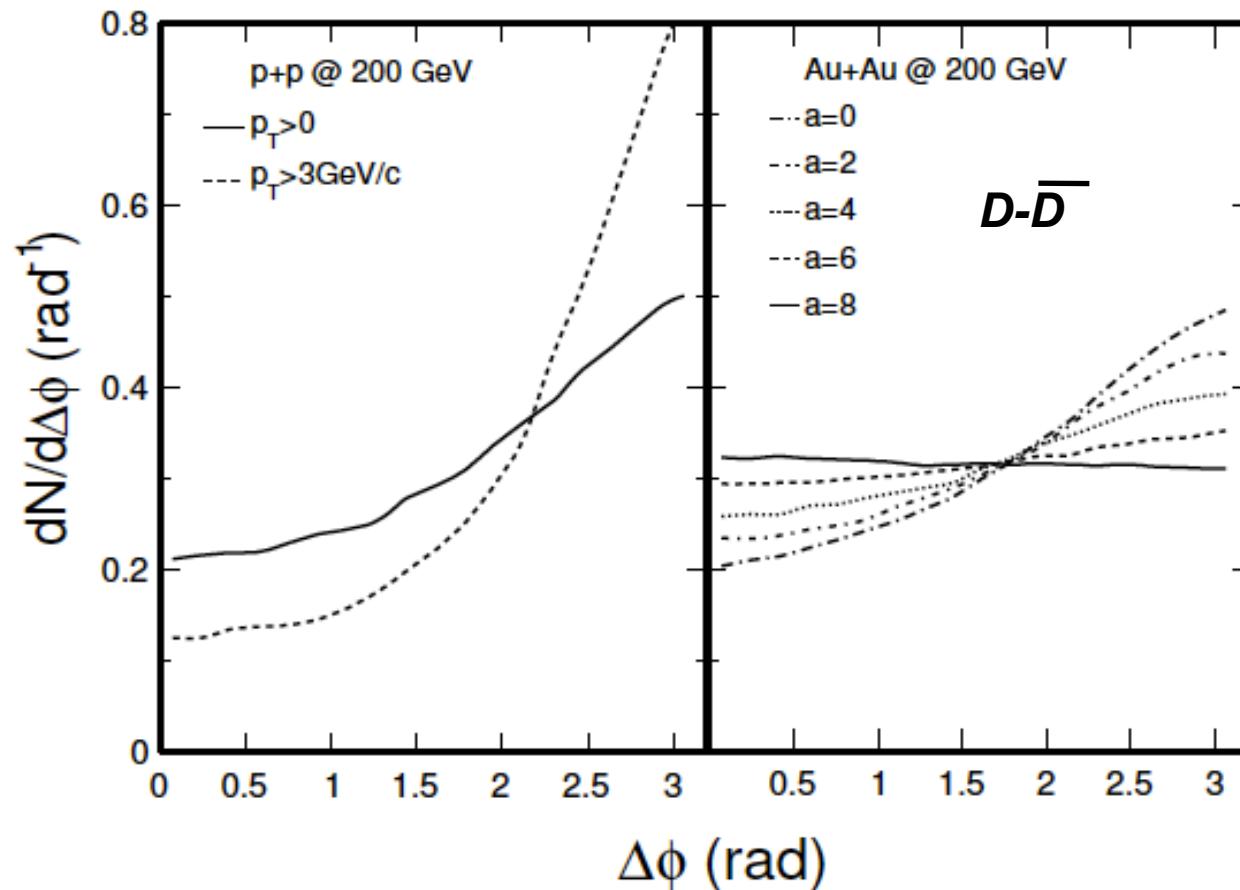


Di-leptons, s-, c-quark hadrons : mass  $\geq 1 \text{ GeV}/c^2$  region:

→ Medium properties: partonic collectivity, temperature

# Heavy Quark Correlations

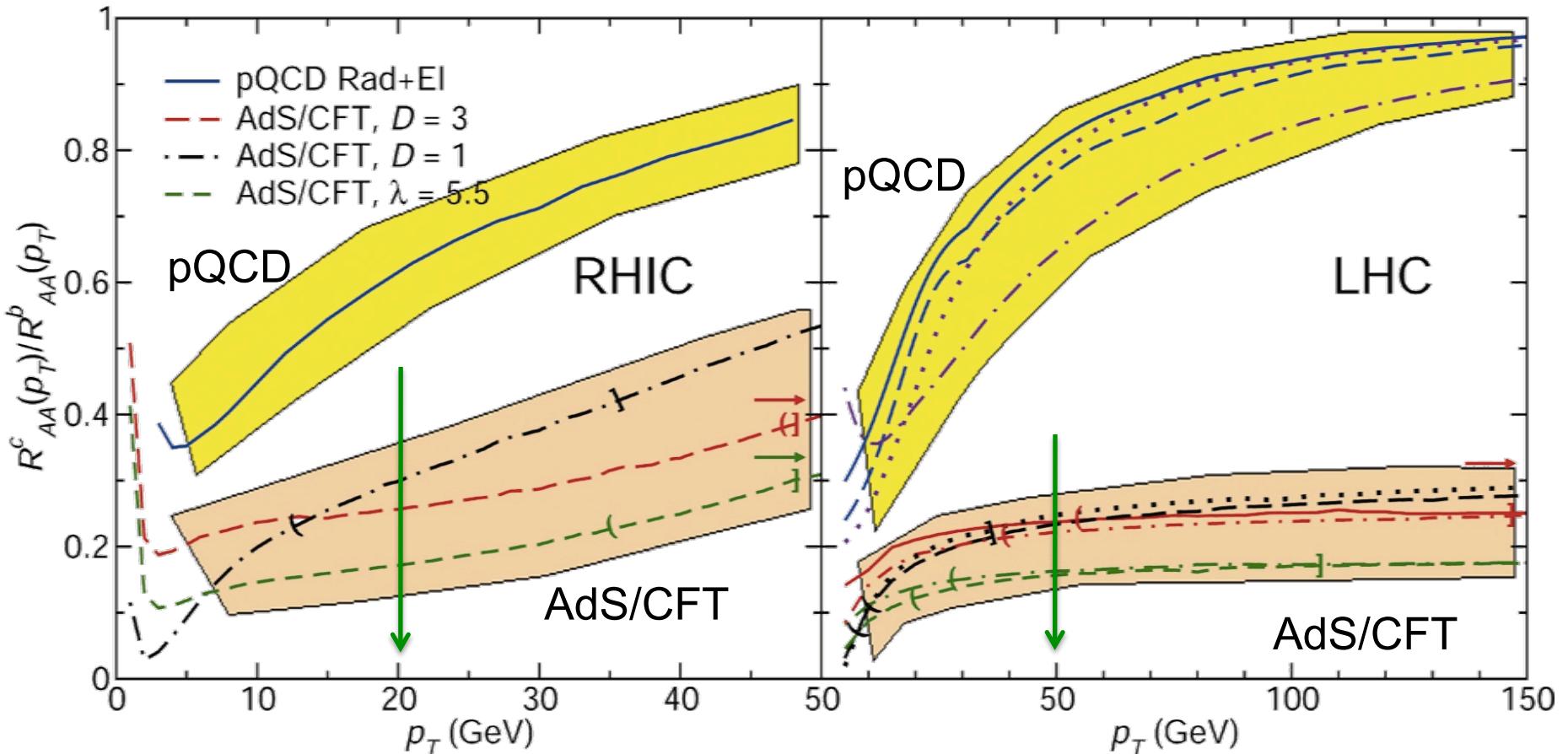
X. Zhu, NX, Pengfei Zhuang, PRL 100, 152301 (2008)



- Heavy quark correlation – probe to quantify the medium properties
- Unique at RHIC – clean production kinematics for physics interpretation in HIC

# Heavy Flavor Energy Loss: Puzzle

W. Horowitz and M. Gyulassy, arXiv:0710.0703



- 1) pQCD calculations include ***radiative + elastic collision*** energy loss
- 2) Both pQCD and AdS/CFT predict  $\Delta E(b) < \Delta E(c)$ !
- 3) Heavy flavor jet trigger needed (At LO, HF-jets conserved)



- 1) Solid-state detector for high-energy experiments**
  - ALICE, RHIC, FAIR, CSR
- 2) Application of the sensors**